

Letter from Alexander Graham Bell to J. A. D. McCurdy, October 22, 1908

Beinn Bhreagh, near Baddeck, Nova Scotia. October 22, 1908. Mr. J. A. D. McCurdy, Hammondsport, N. Y. Dear Douglas:

I have written an article for the Bulletins of the A.E.A. entitled "THE LESSONS TO BE LEARNED FROM ORVILLE WRIGHT'S DISASTER: The causes of the Accident with running comments, by Alexander Graham Bell." We have now completed the Bulletin to be issued Oct. 26 but this article has been crowded out and will have to come in another number. I am anxious, however, to have you and Curtiss read it and therefore enclose a copy. I hope you may be able to get it before your old "Silver Dart" takes the air.

In haste

Yours sincerely, Alexander Graham Bell P.S. I think it important that you and Curtiss should also write your views on the subject. I've got Mr. Baldwin worked up upon the matter disapproving a number of my conclusions so we are sure of a paper from him. Then upon receipt of these communications we will have a fierce discussion here over the matter with our stenographer, Miss Mabel B. McCurdy present making notes. Then all the papers and the discussion will be made the subject of a special Bulletin. A. G. B.

THOUGHTS SUGGESTED BY ORVILLE WRIGHT'S DISASTER: By Alexander Graham Bell.

In the case of the accident the Orville Wright's flying machine, we have reason to believe that a propeller blade caught in one of the rudder wires; and that the propeller and the wire both broke, leaving the machine with a single propeller in operation and with its steering gear out of order.

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Now Orville Wright's two propellers were placed one on either side of the longitudinal axis of the machine. Thus it happened that when the right propeller broke, the left propeller continued pushing, not in the central line of the machine, but on the left side of it; and the machine at once turned sharply to the right.

It is obvious that such a turning action, if not quickly neutralized by steering to the left, would cause the machine to move in a circle of small diameter, or even to spin round like a top, a condition not favorable to support in the air, if indeed not absolutely fatal to it.

The only thing possible for Mr. Wright to do under the circumstances was to shut off power and attempt to glide to the ground. This he did with disastrous results to himself and his passenger.

The fatal result to our friend and associate, Lieut. Selfridge, brings home to us, as nothing else could do, the advisability of studying closely all the causes that could lead to such a catastrophe, so as to avoid them in our future experiments.

2

The accident shows us how careful we should be to see that our propellers have plenty of room; and that there should be nothing near them that could possibly catch, or that could possibly be drawn within reach of a rotating propeller by the powerful suction exerted by one face. The breaking of a propeller in the air may evidently become a serious matter, and we would do well therefore to make absolutely sure that our propellers are constructed of such strong and sound material that they could not possibly break under the centrifugal force generated by their rapid rotation; and that the blades are so stiff that they could not break by bending under the pressure of the air driven from them. In Laboratory experiments we have had propellers smash from all these causes, and we cannot be too careful in our inspection of propellers to be used in actual flight.

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We may learn also from Orville Wright's experience that double propellers, rotating in opposite directions, although exceedingly desirable because they eliminate the disturbing effects of torque and gyroscopic action, introduce an element of danger when arranged as in the Wright machine.

It might perhaps be safer to use concentric propellers both pushing (or pulling) in the central line of the machine. Then if one is put out of commission, the other will continue pushing in the central line and not to one side of it. Some disturbance of equilibrium might still result from unbalanced torque, or gyroscopic action, but the danger would not be so great as when combined with an ex-centric push.

3

With concentric propellers two engines, one for each propeller, might be of advantage; for should one of the engines break down in the air both propellers would not stop. One of them would still continue in action pushing in the central line. It is hardly likely that both engines, or both propellers, would give way at the same time; and, in case of accident to one, the aviator would not be obliged to come down at once without being able to choose his place of descent.

When the accident at Fort Meyer occurred, Mr. Wright did not know exactly what had happened, for the rudder and propellers were behind him, and therefore out of his sight. He did not dare to look round very much, for the operation of his controlling levers demanded all of his attention at the time.

This emphasizes the importance of the suggestion made by Mr. F.W. Baldwin that the moveable parts of an aerodrome should be placed in front of the aviator as much as possible, so that he may keep them under constant observation (see discussion concerning front and rear controls, Bulletin XVI, pp.36–44). If anything went wrong he would then see at a glance what had happened, and would be in a better position to meet the emergency.

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Mr. Baldwin suggests that the vertical rudder should be placed in front of the machine instead of at the rear, like the horizontal rudder known as the "front control". In both cases the natural and proper position would seem to be at the rear; but no inherent reason exists why the vertical rudder should not be able to operate in front, at least as well as the front control.

Where it is impracticable to put moveable parts in front, it might be worth while considering whether a fixed mirror in front might not be of advantage into which the aviator could look and see the moving parts behind him, or on either side, without the necessity of turning his head.

The Wright machine, after the accident, was found with its head pointing in a very different direction from that in which it was going when the propeller broke, suggesting the idea that it had spun around at least 90° before it reached the ground, and had thus lost its motion of translation through the air. Whether or not this was the immediate cause of the disaster to the Wright machine, it is safe to say, that under present conditions of aerodrome construction, loss of headway is the greatest danger the aviator has to fear This, I think, will be admitted by all.

But why should loss of headway be accompanied by danger? This is of the greatest consequence for us to determine for a machine may lose headway at any moment from causes that are quite beyond our control. An engine may break down, a propeller may go, even an unexpected gust of wind may stop our machine for a moment, and at once danger results. What usually happens under such circumstances? The machine turns head down and dives. What does this indicate? That the machine is not properly balanced when headway is lost. The turning down of the head shows that the center of gravity is too far forward for a good balance under the circumstances. The advanced position of the center of gravity is then the cause of the danger.

Now it is somewhat disconcerting to find that the tendency of progress in the Hammondsport experiments has been to advance the position of the center of gravity in our machines. This has been done by bringing the place of the aviator further forward in the machine than before, by omitting the tail, by using a heavier front control, and by putting the front control at a greater distance from the main supporting aeroplanes. We should give grave consideration to the question whether these changes have, or have not, increased the danger to the aviator in the event of loss of headway.

But why should there have been this tendency of progress in our experiments to bring forward the center of gravity. I think it results from the fact that we naturally desire that our machine should be properly balanced when in rapid flight. The June Bug, in its early days used to climb under the full power of the motor. Instead of remedying this defect by the use of a large front control we advanced the place of the man, thus violating the important principle that changes of equilibrium should be balanced by the action of moveable surfaces, rather than by changes in the position of the center of gravity.

The center of pressure of course is further forward when a machine is in motion, than when it is stationary in the air; and, in order to be properly balanced, the center of gravity should come under the center of pressure.

6

The following propositions are important and interesting and should be fully discussed:—

1. If an aerodrome is properly balanced while in rapid motion it will become unbalanced when headway is lost. The head then turns down, with a tendency to continue the turning movement until the head points vertically downwards towards the ground.
2. If the machine is properly balanced when it has no headway, it will become unbalanced when it moves forwards through the air. The head then turns up, with a tendency to continue the turning movement until the head points vertically upwards towards the sky.

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Both are dangerous conditions, but there is a noteworthy difference between them:—

3. We can correct the climbing tendency by steering down with the front control; but we cannot correct the diving tendency by steering up, because there is no headway.

You cannot steer a boat without headway far less a flying machine. The second condition is far safer than the first

When there is no headway the front control can no longer exercise its function as a horizontal rudder. When turned up at a positive angle to the horizon it is no longer pushed up by the pressure of the wind of advance. For the same reason there is no air pressure against it to push it down when turned at a negative angle. It is merely passive in its action and resists the very upward and downward turning movements it would cause in its active condition.

Where the machine is head-heavy when headway is lost, as in the first case noted above the machine tends to turn 7 downwards at the head, and the surface of the front control resists this turning tendency.

At first sight it would appear that by increasing the surface of the front control we could prevent a dive, but consideration will show that this is not so.

When headway is lost, the presence of a front control will not prevent the tendency of a head-heavy machine to turn head downwards, however large its surface may be, or however far out it may be placed in front of the main supporting aeroplanes. The most it can do is to retard the turning movement. It cannot prevent it. The machine retains a tendency to turn completely over until the head points vertically downwards towards the ground.

This is a dangerous tendency not fully realized by us, I think, and the cause not clearly understood by all. Let me try to explain the point.

In a stationary machine if the center of gravity is too far forward for correct balance the machine turns over in front and dives. If it is too far back it turns over backwards and dives stern down; and the safe position for the center of gravity lies somewhere between. Is not this point the geometrical center of surface of the whole machine — the geometrical center of all the surfaces concerned including the front control?

When the machine falls without any motion of translation in the horizontal direction it acquires “downway”, not “headway”; and the geometrical center of surface becomes the center of pressure or resistance.

8

Now as the machine falls the extended surfaces resist the motion, being pushed upwards as it were by the air pressure below. If therefore the center of pressure and the center of gravity are not in the same vertical line, a turning couple is produced which tends to turn the machine around an axis between the centers of pressure and gravity: Or rather, in this case, the center of pressure is itself the axis of rotation, for though the air pushes upwards against the surfaces, it does not succeed in pushing them up, they are falling all the time. It only succeeds in retarding their drop, so that they fall more slowly than the center of gravity and thus produce the turning effect.

Now when there is no headway it appears that the center of pressure is in the geometrical center of surface. If this is so it follows, that if the center of gravity is displaced from that position, either forward or backward or to either side, the machine tends to turn over on the heavy side until the center of gravity comes vertically under the center of pressure. With a head-heavy machine the tendency would be to turn completely over forwards until the head points towards the ground, and no front control could prevent it if the machine has no

Library of Congress

headway. Here lies the danger. It is obvious that we must study the cause of this tendency and combat it if possible. Perhaps a simile may make my position more plain.

Substitute, for the center of gravity, the bob of a pendulum; and, for the center of pressure, the axis which supports it.

9

Now hold the pendulum out horizontally from its point of support and allow it to drop. The pendulum will then turn upon its axis until the bob comes vertically beneath the point of support. No resting place is found until that position is reached.

Now can we prevent this action by giving the pendulum a front control? Prolong the rod of the pendulum as far as you like beyond the bob, and attach to its extreme end a resisting surface which may be as large as you choose. Now hold the pendulum out horizontally as before with the resisting surface also horizontal, and let go. The pendulum will swing more slowly than before on account of the resistance of the front control; but the point I would enforce is this, that the resisting surface however large and however far removed from the axis of rotation, will not prevent the turning movement from continuing steadily to the very end, when the center of gravity comes directly beneath the center of support.

The same is true of an aerodrome which is head-heavy in the slightest degree. The front control will not prevent it from turning completely over, head down, if it has no headway: Only headway can save it.

Now it is noteworthy that an aerodrome with its center of gravity at the center of surface does not have this tendency to continue turning over, even though it should be tipped one way or the other.

10

Suppose it should be tipped slightly down in front. It would begin to slide down an inclined plane; but gravity has no tendency to make the dive become steeper, as would be the

Library of Congress

case were it head-heavy, stern-heavy, or side-heavy. On the contrary, from the very first gravity exerts a corrective influence. As the center of gravity tends to assume the lowest possible position its action is to lower the elevated side of the aerodrome, instead of depressing the lower side still more, thus causing the surfaces of the aerodrome to return to the horizontal position.

This central position of the center of gravity, while it places the aerodrome in the safest condition if it has no headway, has its disadvantages. The surfaces will not remain horizontal for any great length of time, but, under the action of the varying conditions met with in the air, will tip slightly one way or the other.

For example:— Let the surface tip down a little in front, and the machine glides down forwards in stable support so long as its headway is inconsiderable. As more headway is gained the center of pressure moves forward while the center of gravity remains behind at the center of surface. Thus as the machine glides downwards on its inclined path the center of gravity, being behind the center of pressure, leads the machine down behind the axis of rotation, so that gravity over balances the machine backwards performing the function of a rudder to steer the machine up to the horizontal position again. But during this process the machine has gained headway, so that the turning movement would go a little further than 11 the horizontal position and the machine would begin to climb with its surfaces tilted up in front until its headway was exhausted and it came to a stop. The surfaces then being inclined downwards at the rear the machine would begin to slide backwards down an inclined plane, but gravity would not act to increase the inclination. With the re-appearance of headway, which in this case would be stern-way, the center of gravity would be in front of the center of pressure and thus again act as a corrective influence to bring the machine up to the horizontal and beyond.

Suppose that the original inclination should take the form of a tip to one side, then after gliding down hill a little way on that side, the machine would move up until its side-way was exhausted, and then commence a reverse glide down on the other side.

Thus, however the surfaces should happen to tip in the first instance, the machine would fall with an oscillating motion, first moving one way, and then reversing its path.

The inclination that could be most easily controlled by the aviator is the downward tip in front, so that the machine should gain headway rather than stern-way or side-way. This can be secured by having the center of gravity a little in front of the center of surface, only just sufficiently so to prevent to the possibility of a stern tip. When the machine then begins to glide down hill in front, the headway gained will enable the aviator to use his front control as a rudder. The further movement of his machine would then be within his own control.

12

We are here of course dealing with a machine that has lost its motive power, so that the propelling power is gravity alone. The aviator, having secured control must preserve his headway at all hazards, or he will lose his steering power. He should be careful to keep his machine on the down-grade. Should he steer the machine on a horizontal path, or upon an up-grade, the resistance of the air would soon check his advance and he would be helpless until the machine should make another dive.

The important lesson to be learned is that the center of gravity, although it should be in front of the center of surface to secure a front dive when headway is lost, should be as little re moved from that point as possible. The further forward the center of gravity is placed, the quicker will be the turning action produced by gravity and the steeper the dive that is necessary to restore headway.

Those conditions then are important which reduce the rapidity of the turning movement, so that there may be time to gain steering headway before the head has tipped down to a dangerous extent. The conditions that reduce the rate of turning are:—

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1. The center of gravity as near the center of surface as possible, so that gravity may not have much leverage to help the turning movement.

2. The front control very far removed from the main supporting aeroplanes, so as to secure the advantage of leverage in resisting the turning movement.

13

3. Large surfaces upon the front control to increase its resisting action.

4. A horizontal tail very far removed from the main supporting aerodrome aeroplanes, to retard the turning movement by the pressure of air upon its upper surface.

5. A large surface for the tail to increase its resisting action.

All these conditions tend to reduce the velocity of the turning movement, and therefore facilitate the acquisition of horizontal headway before the downward tip has become too steep for safety.

The conditions that increase the velocity of the turning movement, and hence increase the danger to the aviator are the reverse of these viz:—

1. The center of gravity far in front of the center of surface.

2. The front control near the main planes.

3. Small surfaces upon the front control.

4. The tail near the supporting aeroplanes.

5. The tail surface small, or omitted altogether.

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A large front control well removed from the main aeroplanes, and a large horizontal tail equally far removed behind, would give great longitudinal stability to the apparatus; and by this we mean in reality that the vertical turning movements would be slow.

It is desirable, however, that we should be able to steer up or down quickly if we so desire; and by making the front control and the tail both moveable, we secure the very desirable combination of quick steering when both are moved simultaneously so as to co-operate with one another, and slow turning motion when they are both held fixed.

There is still another point about the front control. The location of the axis upon which it turns is important. We are accustomed to place the axis nearer the front edge than the rear, so as to secure the point that when the machine is in rapid motion the center of pressure of the front control shall fall upon the axis. This of course reduces the power necessary to turn it because the air pressures are nearly balanced on either side of the axis.

But how about the operation of the front control when the machine has lost headway? In such a case the main surface of the front control being behind the axis of rotation and the center of pressure being also behind the axis in that case, an unbalanced pressure would exist upon the under surface of the front control when the machine begins to turn down in front for a dive, which tends to lift to the rear of the front control, and cause the front control to be inclined downwards in front thus assisting the dive instead of resisting it. Thus at the most critical time, when headway is lost, it would take more power to move the front control, than under ordinary circumstances when the machine is in motion.

Who knows but what this action may have considerable contributed to the Wright disaster! With surfaces large enough to be difficult of manipulation under the ordinary conditions of rapid flight it may well be possible that the aviator may not have sufficient strength to resist the turning tendency of the front control at a critical moment of time when it is important that the surfaces should offer their maximum resistance to descent. Why would it

Library of Congress

not be safer to place the axis of rotation in the middle of the front control, so as to make it as easy as possible for the aviator to handle it when headway is lost.

If I am right in my various line s of reasoning, it is extremely important that the center of surface of the whole machine, when the front control is held parallel to the main aeroplane surfaces, should not fall behind the center of gravity.

I do not think it did so in the case of the Wright machine. I ma de a rough estimate of the area of the front control of the area of the main surfaces, and of their distance apart, and came to the conclusion that the center of surface, under the conditions specified above, came very near the front edge of the main aeroplanes. The center of gravity appeared to be at about the same point, or a little further back, so that if the surfaces of the front control had been held rigidly in their position of maximum resistance I do not see how a disastrous dive could have resulted. The evidence however seems to point to the conclusion that the apparatus really did make a dive head first.

I can only understand this, upon the supposition that the front control was inclined at the time of the fall, either by the action of the aviator, or by the unbalanced pressure of the air below it when headway was lost.

16

It is obvious that if the surfaces were very much inclined the apparatus might perhaps have become head-heavy; and this head-heaviness would have been increased by the fact that the machine carried two men instead of one both seated at the front part of the lower aeroplane.

Suppose for example that in such a machine the surfaces of the front control should be turned into the vertical position instead of the horizontal, so as to be placed edgeways to gravity, then the whole support of the machine would have been thrown upon the main

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aeroplanes. The center of gravity would then be in front of the center of surface of the main aeroplanes, and the machine would become head-heavy.

Of course it was impossible for the front control of the Wright machine to assume this vertical position on account of limitations to its motion. But if the surfaces were much inclined head-heaviness might perhaps have been produced though in a lesser degree.

Of course it is impossible to say exactly what happened in the case of the Wright machine; but I would urge upon the Hammondsport members to calculate and make sure that the center of surface of the Silver-Dart is not behind the center of gravity when the front control is placed in its most resistant position. I would also have them consider the advisability of placing the axis of rotation in the middle of the front control rather than further forward.

There is one other point and I have done. In an aerodrome without headway a stable condition results when the center of gravity is in the same vertical line with the center of surface.

1. If the center of gravity be vertically above the center of surface, then, though the machine is balanced, it is in a state of unstable equilibrium, like a walking-cane standing upright upon its end.
2. If the center of gravity be below the center of surface, we have a stable condition with a liability to swing, like an oscillating pendulum hung from its support.
3. If the center of gravity and the center of surface are absolutely co-incident, a stable condition results which the action of gravity cannot disturb. This point is well worthy of consideration.

In conclusion it seems to me desirable that the center of gravity should be a little in front, and a little below the center of surface; but that the displacement from this safe position should be as slight as possible, and only sufficient on the one hand to prevent the

possibility of a stern dive, and on the other to be certain that the machine will tend to keep right side up.

The subject of this paper is of so much importance to all the members of the Association that I propose to ask each member to write out his views. There is likely to be considerable diversity of opinion, and this will provoke discussion. The various papers, and the discussion, can form the subject of a special Bulletin. A.G.B.

18

SYNOPSIS OF PRECEDING PAPER.

Orville Wright's disaster described (1); Points for the inspection of propellers (2); Two propellers rotating in opposite directions desirable but they should be concentric (2); With concentric propellers two engines advisable, one for each propeller (3); Moveable parts should be kept in sight and therefore placed in front as much as possible (3); Vertical rudder could be placed in front (3); A mirror could be used to see behind and to either side without turning head (4); Immediate cause of Wright disaster probably loss of headway (4); Loss of headway greatest danger aviator has to fear (4); Why dangerous? Because usually machine not properly balanced when headway is lost (4); Cause of danger? Center of gravity generally too far forward for correct balance when headway is lost, so that machine turns head down and dives (4); Tendency of progress at Hammondsport has been to advance the position of the center of gravity (5); Why? To properly balance machine while it has headway (5); Does this violate principle that changes of equilibrium should be balanced by action of moveable surfaces rather than by changes in position of center of gravity (5); Recommend consideration of question whether Hammondsport changes have increased danger to aviator in event of loss of headway (5); Three Propositions:— Machine properly balanced when it has no headway becomes unbalanced when headway is gained and climbs. Machine properly balanced when it has headway becomes unbalanced when headway is lost and dives. Aviator can steer down to correct the climb because there is headway, but cannot steer up to

Library of Congress

correct the dive because there is no headway (6); Front control cannot operate as a rudder without headway, merely offers passive resistance to turning movement that produces the dive (6); Front control without headway cannot prevent turning movement of head-heavy machine, only retards it, so that it takes longer time for head to turn vertically downwards (7); Condition of machine without headway considered in detail (7); Effects of change in position of center of gravity (7); Center of pressure in geometrical center of surface (7); Balanced when center of gravity and center of surface in same vertical line (8); If center of gravity in front of center of surface machine tends to turn completely over in front till 19 2 head points towards ground and, without headway, no front control can prevent it (8); This position enforced by pendulum simile (9); Center of gravity at center of surface no tendency to continue turning over if machine tips one way or other (9); Gliding down hill with front tipped down no tendency to increase steepness of dive (10); Gravity acts as a rudder to steer it up again (10); Disadvantage oscillates in falling (11); Center of gravity should be a little in front of center of surface, but only sufficiently so to determine that direction of tip shall be in front so as to secure headway rather than stern-way, or side-way (11) The headway gained brings machine under control of aviator (12); He should steer on down grade (12); If he steers on horizontal path, or on up-grade he will lose his headway and then be helpless until another dive occurs (12) Conditions that reduce the steepness of the initial dive (12); Conditions that increase it (13); Horizontal tail and front control both moveable secures great longitudinal stability when both are held fixed, and great quickness of vertical steering when both are moved in co-operation (13); Axis of front control nearer front than rear facilitates manipulation of front control when there is headway but more difficult to operate when headway is lost, requires more power to move it (14); Larger surface of front control being behind axis it is liable to be tilted at negative angle by pressure of air underneath when headway is lost thus assisting a dive instead of resisting it (15); Suggests that axis should be in middle of front control (15); Center of surface of whole machine should not fall behind center of gravity (15); Not behind in Wright machine when front control parallel to main surfaces (15); Machine become head-heavy with front control inclined (16); Was it inclined at time of accident (16);

Library of Congress

Recommendation to make sure that center of surface of Silver-Dart is not behind center of gravity when front control in most resistant position (16); When machine balanced without headway if center of gravity is above center of surface equilibrium unstable; if below, it is stable with tendency to swing like a pendulum, if the two centers are co-incident gravity has no tendency to disturb the balance (17); Recommendation that center of gravity should be slightly in advance and slightly below center of surface, but as little as possible consistently with prevention of stern dive, and keeping right side up (17). A.G.B.